THE SOFT X-RAY EXCESS AND THE BIG BLUE BUMP IN QUASAR

NASA Grant NAG5-1883

Final Report

For the period 15 March 1992 through 14 March 1994

Principal Investigator
Dr. Belinda Wilkes

March 1994

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Dr. Robert Petre, Code 666, Laboratory for High Energy Astrophysics, Space Science Directorate, Goddard Space Flight Center, Greenbelt, Maryland 20771.

All outstanding ROSAT data have now been received and analysis is currently underway or completed. Multiwavelength follow-up (optical spectrophotometry, optical imaging, infra-red photometry and ultraviolet spectrophotometry) of these targets is also nearing completion. The remaining observations are expected to occur over the next couple of months and include 1 IUE spectrum, 6 optical spectra and IR and optical photometry of about 20 objects. The data in hand is currently being reduced ready for analysis. I summarise below the main results and the papers in which they are reported.

1 Scientific Results:

1.1 Absorption:

We have discovered that soft X-ray absorption is common in high luminosity, radio-loud quasars at high redshift. Current evidence suggests that it may be related to dense gas surrounding the quasar which also encloses the radio emission for the radio-loud objects. The radio-quiet objects show less absorption and look similar to their low-redshift counterparts.

Absorption is also present in two low-redshift quasars: 3c351 and 3c212. The former also shows strong ultraviolet, metal-line absorption whose properties are consistent with the X-ray absorber, which is warm. This is the first time that X-ray absorption has been linked to that at other wavelengths and opens up very exciting possibilities for study of absorption as the combination of ultraviolet and X-ray data allows us to place strong constraints on the physical conditions of the absorber. Such constraints have not been possible to date.

1.2 The X-ray spectrum:

The X-ray slope of quasars does not change significantly with redshift when the same rest frame energy range is considered. In low-redshift objects, the slope (both mean and in individual objects) seen in the soft ROSAT PSPC energy band (0.1-2 keV) is steeper by about 0.5 in index than that observed at higher energies (eg. .2-3.5 keV, Einstein IPC). Since no sharp change in slope is seen, this implies that some curvature is present in the spectra. Currently strong constraints cannot be placed on the form of this curvature as there remain unresolved cross-calibration problems between the two detectors which are being investigated.

1.3 Spectral Energy Distributions (SEDs):

The X-ray slope and optical to X-ray ratio are correlated in our PG sample. This correlation implies that a hard X-ray component is present in varying strengths. The X-ray slope is also correlated with a few emission lines properties, eg. [OIII] flux, Hbeta FWHM. The cause of these correlations is not immediately apparent. The correlations are being further investigated using a larger sample.

The IR-X-ray SEDs of a few low-redshift quasars have been compared with accretion disk and free-free models for the blue bump component. Neither model matches the data in

their simplest form. Modifications to the accretion disk model, such as the inclusion of an electron-scattering atmosphere, are able to match the data better.

1.4 X-ray luminosity functions and evolution:

We have completed a mid-depth survey ($f > 2 \times 10^{14}$ erg/s/cm^2) of the central regions of 20 PSPC fields. The survey contains 123 sources, 66 of which are confirmed quasars and 14 have strong, narrow emission lines. We derived the evolution rate to be steeper than that found in earlier X-ray surveys: L$\sim (1+z)^{3.2}$; and more in line with optical surveys, in which the power is typically 3.5. The narrow-line objects are potentially an important contributor at fainter X-ray luminosities which had not previously been recognized.

2 Publications:

We have prepared a number of papers which are in various stages of submission:

PKS0438-436: a high redshift quasar with strong X-ray absorption (B. J. Wilkes, M. Elvis, H. Tananbaum, J. C. McDowell and A. Lawrence) Ap.J.Lett **393**, L1

The ROSAT Spectrum of 3C351: A Warm Absorber in an X-ray 'Quiet' Quasar (F. Fiore, M. Elvis, S. Mathur, B.J. Wilkes and J. McDowell) *Ap.J.* **415**, 129

X-ray Absorption toward the Red Quasar 3C212 (M. Elvis, F. Fiore, S. Mathur and B.J Wilkes *Ap.J. in press*

Absorption in X-ray Spectra of High Redshift Quasars (M. Elvis, F. Fiore, B. Wilkes and J. McDowell) *Ap.J.* **422**, 60

The Complex Optical to Soft X-ray Spectrum of Low-redshift, Radio-quiet Quasars. I: The X-ray Data. (F. Fiore, M. Elvis, J.C. McDowell, A. Siemiginowska, and B.J. Wilkes) *Ap.J. in press*

The Complex Optical to Soft X-ray Spectrum of Low-redshift, Radio-quiet Quasars II: The Broad-band Spectral Energy Distributions. (Fabrizio Fiore, Martin Elvis, Aneta Siemiginowska, Belinda J. Wilkes, Jonathan C. McDowell and Smita Mathur) 1994 *Ap.J. submitted*

The X-ray and Ultra-violet Absorbing Outflow in 3c351 (S. Mathur, B. Wilkes, M. Elvis and F. Fiore) *Ap.J. submitted*

The Soft X-ray Properties of a Complete Sample of Optically Selected Quasars. I. First Results. (A. Laor, F. Fiore, M. Elvis, B. Wilkes and J. McDowell) *Ap.J. submitted*

Infrared to X-ray Spectral Energy Distributions of High Redshift Quasars. (J. Bechtold, M. Elvis, F. Fiore, O. Kuhn, R. Cutri, J. C. McDowell, M. Rieke, A. Sziemiginowska and B.J. Wilkes) *A.J. submitted*

X-ray Spectral Evolution of High-Redshift Quasars (J. Bechtold, M. Elvis, F. Fiore, O. Kuhn, R. Cutri, J.C. McDowell, A. Siemiginowska and B.J. Wilkes) *A.J. submitted*

The Cambridge-Cambridge X-ray Serendipity Survey: I X-ray Luminous Galaxies. (B.J. Boyle, R.G. McMahon, B.J. Wilkes and M. Elvis *MNRAS submitted*

The Cambridge-Cambridge X-ray Serendipity Survey: II The Data (B.J. Boyle, R.G. McMahon, B.J. Wilkes and M. Elvis *in preparation*